

Lat 39.30008 Lon -120.32950

Forest Health Protection

Pacific Southwest Region



Date: May 20, 2003
File Code: 3420

To: District Ranger, Truckee Ranger District, Tahoe National Forest

Subject: Preliminary Field Evaluation of the Sugar Bowl Ski Area (FHP Report NE03-04)

Tree health concerns at the Sugar Bowl Ski Area prompted a field visit on April 25, 2003. Bill Williamson, Resort Operations Director for Sugar Bowl, Bob Moore, District Winter Sports Specialist, John Minutilli, District Culturist and myself skied several of the runs to obtain an overview of the area and conduct a preliminary evaluation related the dead and dying western white pine and red fir that Bill had observed. Views and access to some areas were limited due to weather conditions.

This report serves as a preliminary review of my findings. At your request, a more in-depth field review can be conducted this summer when more detailed information can be collected on the ground.

The Sugar Bowl Ski Area sits to the west of Mount Judah and is included in both the Summit (060) and Tinkers (071) Management Areas in the Tahoe National Forest Land and Resource Management Plan. The resource management emphasis for both management areas centers around recreation. In addition to the privately held portion of the ski area, Sugar Bowl uses portions of National Forest System lands for their operation under permit (see attached map).

NORTHEASTERN CALIFORNIA SHARED SERVICE AREA
2550 RIVERSIDE DRIVE
SUSANVILLE, CA 96130
530-257-2151

Sheri Lee Smith
Supervisory Entomologist
ssmith@fs.fed.us

Daniel Cluck
Entomologist
deluck@fs.fed.us

Bill Woodruff
Plant Pathologist
wwoodruff@fs.fed.us

The Sugar Bowl Ski Area occupies an elevational range between about 6,800 feet in the northwest portion up to 8,200 feet at the top of Mount Judah. Average annual precipitation is about 54 inches. Except for occasional summer thunderstorms, this falls entirely as snow. The areas we skied were dominated by red fir and western white pine. A few signature juniper trees exist under the Jerome Hill lift. Mountain hemlock trees also occur however we did not spend any time evaluating them due to the weather conditions.

Western white pine (*Pinus monticola*)

Western white pine is a seral species that is present in a number of habitat types, associations, and communities throughout its range. It is a native, evergreen, monoecious tree, which can reach 200 feet in height and over 8 feet in diameter. The root system consists of a taproot and lateral roots which can spread up to 26 feet. Most of the lateral roots are in the upper 2 feet of the soil.

Western white pine, when dormant, is tolerant of cold and along with lodgepole pine is one of the more frost-tolerant species. Needle desiccation can occur when cold, drying winds cause excessive loss of moisture that cannot be replaced fast enough because of cold or frozen soil or tree trunks. Western white pine is more tolerant of heat than most of its more shade-tolerant associates.

Observations

Many of the ski runs are lined by western white pine in the pole size to large diameter tree class. There appeared to be a great lack of young regeneration. Several of the large trees have extensive branch flagging and many of the smaller trees have top kill. Whole tree mortality was confined to the smaller size class trees. White pine blister rust is the agent causing the flagging and top kill. The lower boles of the top killed trees had pitch tubes, emergence holes and woodpeckering indicative of successful attacks and subsequent whole tree mortality caused by mountain pine beetle. Mountain pine beetle strip attacks were observed on some of the large trees, however, as mentioned above, mortality of the large diameter trees was not readily apparent. Strip attacks can be common on stressed trees. Over time, the strip attacks can result in mortality.

Management Considerations

White pine blister rust

The most serious damaging agent of western white pine is white pine blister rust, *Cronartium ribicola*. This rust was introduced into this country at the turn of the century from infected seedlings imported from nurseries in France. White pine blister rust has a life cycle requiring alternate hosts for its completion: five-needled pines and currants/gooseberries (*Ribes* spp.). The spores germinate on the needles and use the stomatal openings as entry courts into needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* to continue the cycle.

Although blister rust may spread hundreds of miles from pines to *Ribes*, its spread from *Ribes* back to pines is usually limited to a few hundred feet. Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers (these are called lethal cankers). Bole cankers result in girdling and death of the tree above the canker. Cankers whose closest margins are more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result (these are called non-lethal cankers).

Selection of naturally rust-resistant trees for seed sources for natural regeneration and planting rust-resistant nursery stock may keep future damage from blister rust minimal. I am checking into the status of the western white pine rust-resistant program and the availability of seed sources.

Bark beetles

The bark beetles are the most important group of insects that attack western white pine. The mountain pine beetle, *Dendroctonus ponderosae*, often attacks trees weakened by blister rust as noted in the Sugar Bowl area. The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. In general forest situations maintenance of tree health is the best prevention against mountain pine beetle attacks. During periods of drought stress or when other agents cause stress (pathogens, dwarf mistletoe, fire damage, etc.) high value trees can be treated with insecticides to prevent beetle attacks. Additional information regarding chemical selection and method and timing of application can be provided upon request.

Windthrow

Depending on the site, western white pine is relatively windfirm, but considerable damage can occur from windthrow. In addition, snow often causes breakage in young pole stands. Prompt removal in the spring of windthrown trees or snow breakage material should limit infestations by slash breeding *Ips* beetles. Considerable top kill and whole tree mortality caused by pine engraver was detected throughout northeastern California over the past few years due to drought conditions. Populations of beetles, as evidenced by mortality and top kill, are likely considerably higher now than during non-drought periods. Additional attention should be directed toward slash/windthrow treatment for the next couple of years in general forest areas and always in high value areas.

Red fir (*Abies magnifica*)

Red fir dominates large areas of high country that are a major source of water, especially in California. California red fir occurs in pure, dense forests between the lower montane white fir or mixed-conifer forests and the upper montane or subalpine lodgepole pine and mountain hemlock forests. It has a tolerance for frost and appears to be more sensitive to drought than white fir or the associated pines. A tendency of red fir to grow poorly where snowmelt water

collects, as on mountain meadows, indicates a moderate sensitivity to high soil moisture content during the growing season.

Observations

All size classes of red fir are present throughout the Sugar Bowl area. Most notable on the large trees were signs of infection by dwarf mistletoe and *Cytospora* canker. Some trees have high levels of branch flagging, branch swelling and brooming. Many of the understory trees have high levels of dwarf mistletoe and are being killed by the fir engraver beetle. Small to sapling size regeneration existing under dwarf mistletoe infested trees are dead/dying due to high levels of dwarf mistletoe infection.

Management Considerations

Dwarf mistletoe

Red fir dwarf mistletoe, *Arceuthobium abietinum* f. sp. *magnificae*, is common throughout the range of red fir in California. It is seed-bearing plant that parasitizes only red fir. Heavily infected trees suffer significant growth losses and are subject to attack by *Cytospora abietis*, a fungus that kills branches infected by dwarf mistletoe and further reduces growth. Because of reduced vigor, infected trees are more susceptible to diseases and fir engraver attack. Heart rots, entering through open mistletoe stem cankers can also increase mortality indirectly through stem breakage.

Fruit mature in the fall and disseminate seed in September and October. The seeds are explosively discharged from the fruit through the buildup of turgor pressure. Seeds normally have an upward trajectory. Red fir dwarf mistletoe does not spread rapidly following establishment. Vertical spread in a tree averages less than 3 inches per year. Horizontal spread in a stand without overstory infection is also quite limited. The dense foliage of red fir limits spread because of the high probability of interception of the seed. Spread from infested overstory to understory may be up to about 100 feet, but it is usually less; the actual distance is dependent on slope, wind, and other factors. Trees less than 3 feet tall have a very limited chance of infection because of their small target size.

Several options are available to reduce the effect of dwarf mistletoe in developed recreation areas. The actual treatment prescribed depends on the current conditions of the site and upon the management objectives for the area. Available treatments include selective removal of heavily infested trees, overstory removal of the infected species, and regenerating with non host species. These are discussed in more detail below (Appendix A). These treatments are not mutually exclusive, but may be combined in any particular area to achieve the desired objectives.

Cytospora canker (caused by *Cytospora abietis*)

Cytospora abietis is a canker-causing fungus that infects true firs throughout their range. In California, white fir and red fir are the species most commonly attacked. It is a weak parasite that attacks trees weakened by disease, drought, fire, insects, or human disturbance. It is most commonly associated with dwarf mistletoe infection, and sometimes attacks as many as a quarter of the mistletoe-bearing branches, killing many each year. The bright red flags of recently-killed branches on dwarf mistletoe-infected red firs are almost always the result of lethal *Cytospora* infections. *C. abietis* occasionally reaches especially damaging proportions in certain years, and may attack trees of any age, sometimes killing in top kill or whole tree mortality of young trees.

No direct control of *Cytospora* canker is known, but certain measures can be under taken to reduce damage from this disease. Avoid activities that weaken or damage trees. Take all measures possible to reduce damage to residual trees during any management activities. Open wounds provide entry courts for infection and the additional weakening of the trees through scarring, root damage, and soil compaction predispose them to attack by *Cytospora*. Avoid sudden exposure of understory true firs to strong light and high temperature. Weakening of trees from sudden exposure, in addition to wounding, can lead to severe buildup of this disease. Removal of dwarf mistletoe-infected trees can reduce the buildup of both dwarf mistletoe and *C. abietis* infection in surrounding trees.

On recreation sites and high use areas more intensive measures may be undertaken to control this disease. Pruning and disposing of infected branches can reduce the chance of repeated infection and inoculum buildup.

Fir engraver (*Scolytus ventralis*)

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater than 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without first killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium has been killed.

Fir engravers bore into any member of the host species on which they land, but establish successful galleries only in those which have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Diseases, especially Annosus root disease, drought conditions, and overstocking play a significant role in weakening trees to the point of successful attacks by the fir engraver beetle. At Sugar Bowl, fir engraver attacks were only found on trees with high levels of infection by dwarf mistletoe and cytospora canker indicating that these agents are greatly contributing to tree stress. Maintenance of tree health and vigor is the best defense against fir engraver attacks.

Mountain hemlock (*Tsuga mertensiana*)

Mountain hemlock is usually found on cold, snowy subalpine sites where it grows slowly, sometimes attaining more than 800 years in age. Areas occupied by mountain hemlock generally have a cool to cold climate that includes mild to cold winters, a short, warm to cool growing season and moderate to high precipitation. Annual and summer precipitation and the proportion of precipitation as snow show notable latitudinal climatic trends in the range of mountain hemlock. Mountain hemlock is not well adapted to droughty sites or sites with high evaporative demand.

Observations

We were unable to get to the areas with mountain hemlock due to the weather conditions. Further investigation is required if there are specific concerns associated with this species. Diseases and insects found on mountain hemlock are briefly described below for your information.

Diseases

Common fungal pests of mountain hemlock in the Sierra Nevada include several heart rots (*Heterobasidion annosum*, *Phellinus pini*, *Fomitopsis pinicola*, and *Phaeolus schweinitzii*), of which Indian paint fungus (*Echinodontium tinctorum*) is perhaps the most common and damaging. Several needle diseases and a snow mold (*Herpotrichia nigra*) also attack mountain hemlock, but are not considered serious.

The mountain hemlock race of hemlock dwarf mistletoe, *Arceuthobium tsugense*, is a potentially damaging parasite that causes witches' brooms, reduction in vigor, and occasionally death. It is found throughout most of the range of mountain hemlock.

Insects

Several defoliating insects, bark beetles, and wood-boring insects attack mountain hemlock but typically do not cause extensive damage. *Pseudohylesinus tsugae* and *Scolytus tsugae* attack the boles and large branches and *Pityophthrus* spp. are commonly found in the twigs and small branches. Trees are not typically susceptible to attack by these beetles unless under stress.

Windthrow

Mountain hemlock is very susceptible to windthrow due to its shallow root system. Snow breakage is also common.

Additional Management Concerns

Protecting trees from construction damage.

Trees can be damaged or killed by a wide variety of construction activities. Some practices lead to obvious injuries such as broken branches or torn bark. Open wounds of this type deplete a plant's energy resources and provide entry points for insects or diseases. Often times during construction or other management activities the worst damage to trees often remains hidden underground. It is critical on desired residual trees to protect roots that lie in the path of construction.

Site Clearing/ Thinning

Removal of a large number of trees exposes the residuals to new conditions. Sudden increases in amounts of sunlight and wind can stress trees. Thinning in areas where high winds are a common occurrence should be conducted with extreme caution.

Soil Compaction

Limiting soil compaction around high value trees is highly recommended. Tree roots need loose soil to grow, obtain oxygen, and absorb water and nutrients. Heavy machinery, stockpiling of building materials and excessive foot traffic can all damage soil structure. Lack of good soil aeration can cause roots to suffocate and tree health to decline.

Avoid activities within the primary root zone.

The primary root zone is typically defined as the "dripline" or the area directly below the branches of the tree. It should be noted, however, that roots can extend beyond the longest branches and measures should be taken whenever possible to protect additional area beyond the dripline.

Moving large amounts of soil within the primary root zone usually kills a tree. Except where absolutely necessary, avoid disruptions to the natural contour of the site or shift them well outside the primary root zone.

As much as 40 percent of a tree's root system could be cut during trenching or road building. This reduces water and nutrient uptake, and may compromise the stability of the tree. Sidewalks, driveways and roads located too close to a tree endanger its health and may threaten pavement stability. Factors such as frost heaving, poor drainage, and pavement flaws give roots an opportunity to expand, gain a foothold, and cause damage.

Stump treatment

Annosus root disease, caused by *Heterobasidion annosum*, is common in all conifer stands. Infection is spread from tree to tree by root contact, forming disease pockets in the stand that slowly expand. Infection of freshly cut stumps or new wounds by aerially spread spores creates new infection centers. Infected trees suffer root decay, butt decay, and root mortality. Infection

results in reduced vigor, windthrow, predisposition to attack by bark and engraver beetles, and outright mortality.

Stump infection by *H. annosum* can be largely prevented by treating freshly cut stump surfaces with a borate product. Sporax is the only fungicide registered for controlling annosus root disease on stumps in California. In California, stump treatment is required in recreational areas on National Forest Lands due to the high value of the trees and is highly recommended for lands under private ownership within the Sugar Bowl Ski Area.

Snow breakage and windthrow of pines.

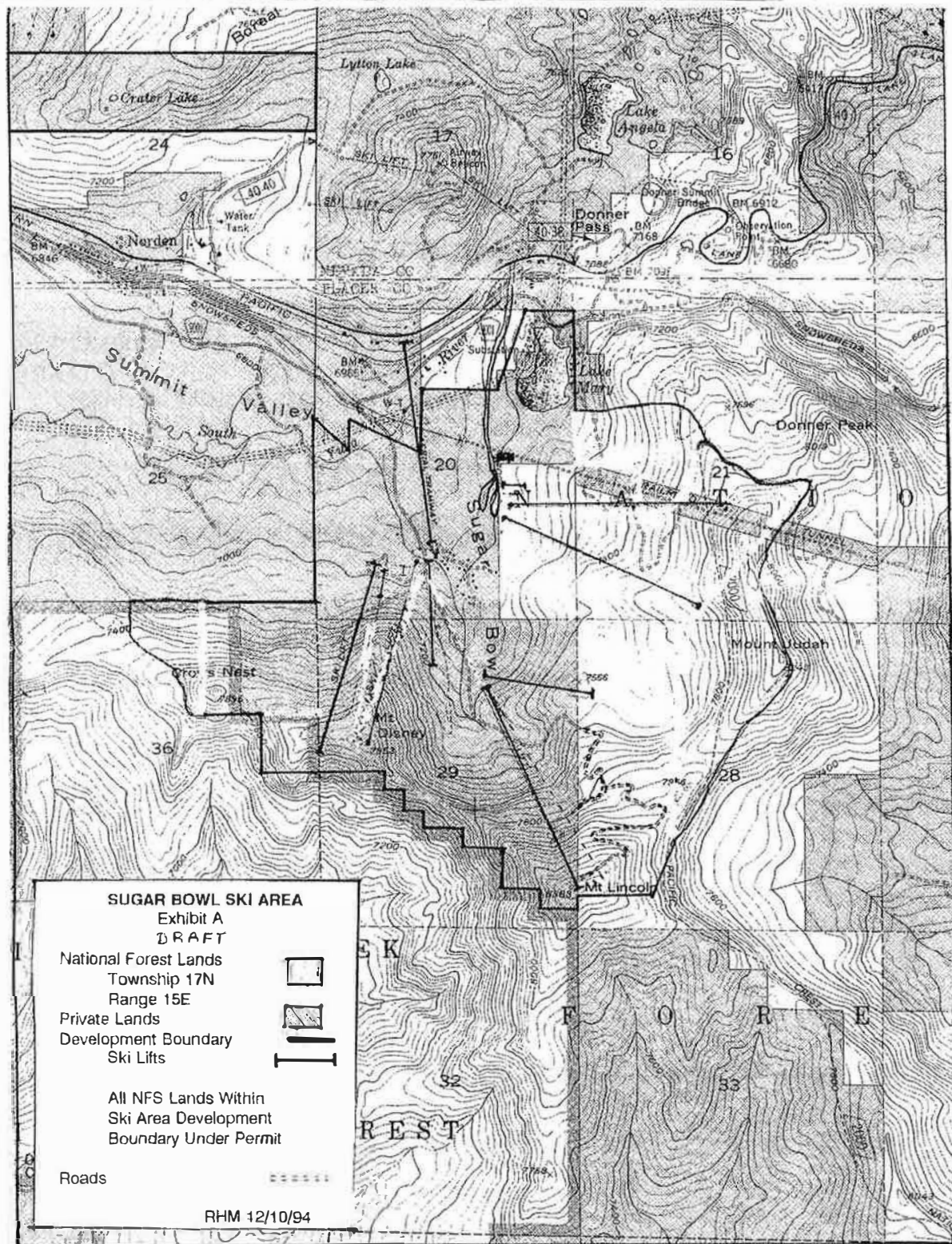
Prompt removal in the spring of windthrown lodgepole or western white pine or and any pine snow breakage material should limit infestations by slash breeding *Ips* beetles. In addition, any green pine trees or pine slash remaining from construction or tree removal should be chipped, burned or removed from the site to prevent infestation.

If you have any questions, would like additional information, or a follow-up visit this field season, please contact me at 530-252-6667 or via email at ssmith@fs.fed.us.



/s/ Sheri Lee Smith

Sheri Lee Smith
Supervisory Entomologist
Forest Health Protection
NE CA Shared Service Area



JIM ZALOSKI SKI AREA BILL WILLIAMS - MT. LINCOLN

White pine blister rust, *Cronartium ribicola*

White pine blister rust is caused by an obligate parasite that attacks all five-needle pines and several species of *Ribes*. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes*. The disease occurs throughout the range of sugar pine and western white pine to the Breckenridge area in the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality. Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves re-infect other *Ribes* throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* leaves in the fall. Teliospores germinate in place to produce spores (sporidia), which are wind-disseminated to pines and infect current year needles.

Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes* its spread from *Ribes* back to pines is usually limited to a few hundred feet. Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers (these are called lethal cankers). Bole cankers result in girdling and death of the tree above the canker. Cankers whose closest margins are more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result (these are called non-lethal cankers).

Environmental conditions are critical for successful infection and limit the disease in most years. Moisture and low temperatures favor infection of both hosts, and must coincide with spore dispersal for infection to occur. In California, these conditions occur only infrequently, usually in cool moist sites such as stream bottoms or around meadows. In so called "wave years" when favorable conditions occur, high levels of infection can result. Wave years in California have occurred at approximately ten-year intervals in the past. As one moves from sites most favorable for rust to less favorable sites, the frequency of wave years decreases.

Red fir dwarf mistletoe, *Arceuthobium abietinum* f. *sp. magnificae*

Red fir dwarf mistletoe is a seed-bearing plant that parasitizes only red fir. It will not survive without living host tissue, which it depends on for support, food, nutrients, and water. Dwarf mistletoes initiate their life cycle when a seed lands on a needle or small twig of a host. The seed is coated with viscin, a sticky substance that allows it to adhere to the host tissue. During rains, the viscin becomes mucilaginous, allowing the seed to slide down to the needle base where it may lodge. The seed germinates in the winter or spring and the radicle grows along the twig until it reaches a needle base or bark irregularity. The radicle forms a holdfast and penetrates the twig into the xylem. A type of root system then develops in the twig. In 3 to 5 years from seed deposition, most successful infections will appear as branch swellings and will bear mistletoe shoots. These shoots will not produce fruit until at least 5 years following seed deposition, the

average being 8-9 years. Fruit mature in the fall and disseminate seed in September and October. The seeds are explosively discharged from the fruit through the buildup of turgor pressure. Seeds normally have an upward trajectory.

Red fir dwarf mistletoe does not spread rapidly following establishment. Vertical spread in a tree averages less than 3 inches per year. Horizontal spread in a stand without overstory infection is also quite limited. The dense foliage of red fir limits spread because of the high probability of interception of the seed. Spread from infected overstory to understory may be up to about 100 feet, but it is usually less; the actual distance is dependent on slope, wind, and other factors. Trees less than 3 feet tall have a very limited chance of infection because of their small target size.

Treatments

Removal of infected trees.

Heavily infected trees are more susceptible to successful fir engraver attack. Removal of these trees reduces the potential for buildup of fir engraver populations in the stands and also lowers overall stocking levels to concentrate moisture and nutrients toward healthier trees.

Overstory removal of infected trees.

When the overstory is heavily infected and their number limited, the most benefit may be gained by removing these trees. This will eliminate the overstory source of infection, allowing the understory of the same species to grow without constant exposure to dwarf mistletoe seed. It may also increase the amount of light, moisture and nutrients available to the understory.

Regenerate with non-hosts.

When it is desired to maintain an infected overstory, but an understory is also needed for future replacement trees, it is advisable to regenerate with species that are not host to the dwarf mistletoe species that is present. It may be necessary to remove some overstory trees to allow light to penetrate to the understory and permit adequate growth. In this case, if possible, it is advisable to remove the more severely infected overstory trees.

Cytospora canker, caused by *Cytospora abietis*

Cytospora canker is a parasitic fungus that causes cankers and dieback of true firs in the western United States. In California, white fir and red fir are most commonly attacked and damaged by this fungus. *Cytospora* attacks trees of all ages. Branch and top killing are very common, and small seedlings and samplings are often girdled and killed. Development of the fruiting bodies takes place in the dead bark tissues. Spore production occurs in the spring and summer, usually during periods of rain or high moisture. Infection is by the spores produced from the fruiting bodies imbedded in the bark of an infected branch. The spores are waterborne and spread during rains. Bark beetles and other insects may also transmit the spores. Infection takes place through wounds and other openings in living branch tissues. Following infection, the fungus grows into and kills the cambium and inner bark. Elongated cankers are often produced as growth of the fungus is about twice as fast longitudinally along a branch as it is around the branch circumference. The fungus girdles and kills most branches in about 6 months to 2 years. Large branches and boles are girdled more slowly.

The most notable symptom of infection is dieback or flagging of branches, tops and small trees. Foliage is initially brick red in late spring and early summer and turns to light brown later in the summer and fall. Dead foliage may remain on the branches for 2 to 3 years. Flagging is particularly noticeable in stands infected with dwarf mistletoe. This disease often forms cankers. Sunken cankers are common, but cankers showing little sunken tissues do occur. Cutting the bark away from the suspected infection often will show the margin between living tissue and the canker. Some branches, usually small ones, are girdled and killed by the fungus with no canker development. On small trees infection of the bole may occur through side branches.

Branches infected by *Cytospora* often exude resin or "pitch". Resin exudation usually appears near the margin of the living and dead tissues. Old infections, generally on large branches and trunks, show a noticeable amount of resin accumulation on the dead bark surface as well as near the canker margin. Small branches or seedlings killed quickly by *Cytospora* may show no resin exudation. The fruiting bodies are small, blister-like structures imbedded in the bark of a dead branch or in the dead tissue of a canker. They are quite small and abundant and give the bark portion of the branch where they occur a warty appearance. When fruiting bodies mature, they produce spores in great abundance. These usually occur in "spore horns", which look like small, curly, yellow threads arising from the blisters and consist of many spores held together by a sticky material. When spore horns are wet, the spores are dispersed in water.

Generally *Cytospora* is a weak parasite, but it can assume epidemic proportions when trees are injured, weakened, or predisposed by adverse conditions to attack. Dwarf mistletoe also commonly predisposes both red and white fir to attack by *Cytospora*. Dwarf mistletoe swellings provide openings in the bark for infection, and a favorable environment for growth and development of the fungus.

Mountain Pine Beetle, *Dendroctonus ponderosae*

The mountain pine beetle attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

Evidence of Attack

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. Besides having pitch tubes, successfully infested trees may have dry boring dust in the bark crevices and around the base of the tree. Infested trees can also have boring dust, but not pitch tubes. This may be common in drought years when trees produce little pitch. Attacking beetles transmit spores of blue stain fungi. As the fungi develop and spread throughout the sapwood it interrupts the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

Life Stages and Development

The beetle develops through four stages: egg, larva, pupa, and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is the general rule, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones that attract males and other females until a mass attack overcomes the tree. The adults bore long vertical egg galleries and lay eggs in niches along the sides of the gallery. The hatching larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

Conditions Affecting Outbreaks

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from pine trees can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include low winter temperatures, nematodes, woodpeckers and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and mortality increases.

Fir Engraver, *Scolytus ventralis*

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater than 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without first killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are greater than 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate successful attacks or subsequent tree mortality. Resin canals and pockets in the cortex of the bark are part of the tree's defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes that are often formed when bark beetles attack pine are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or all of the bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry a brown staining fungi, *Trichosporium symbioticum*, into the tree which causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those which have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality particularly in

areas of low annual average precipitation. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.